Assessment of Locally Sourced Biomass Energy for Residential Thermal Demand

Tompkins County, New York

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Executive Summary

This report will aim to address the potential for locally sourced biomass energy to meet the residential thermal heating demand of Tompkins County. This approach will focus primarily on utilizing existing local forest resources for biomass energy, and secondarily on biomass crop potential of marginal inactive farmland and grassland. Going forward, certain factors need to be studied in detail in order to progress toward any sort if implementation of a biomass production system.

The first step is to analyze the land area constraints by considering the land cover of Tompkins County. Areas that are unsuitable for biomass production include those that are steep, in unique natural areas, near streams and roads, as well as areas that are in parcels too small to be realistically feasible. It was determined that approximately 57,000 acres of the 140,262 acres of forest land in Tompkins County is accessible. Also, approximately 35,000 acres of the 53,000 acres of inactive agriculture and grassland was deemed available for bioenergy crop production.

The second step is to analyze the two types of resources and the assumed yield constraints that they have in terms of annual tons per acre. Although there are many types of potential biomass resources, this report will focus on the two basic forms of biomass feedstock for rural residential heating purposes: forest wood and biomass crops. Additionally, biomass crops will be broken down to two main types: woody biomass that is exemplified by willow, and grass biomass that is exemplified by switchgrass. According to local experts, these two types of bioenergy crops have the most potential for this purpose.

By using these two constraints, of land area and yield, it is determined that the residential thermal needs of Tompkins County could be met by converting almost a quarter of the land area into biomass energy production. Wood residue from the available forests could provide 63,000 dry tons of biomass annually, while biomass crops grown on available inactive agriculture and grassland could produce 165,000 dry tons of biomass annually. Local forests could provide enough biomass to heat 12,000 homes annually, or 29% of the total homes in the county. Although having less land area, biomass crops provide higher yield and could produce enough biomass to heat 30,000 homes annually, or 72% of the homes in the county. Together, these two resources can meet 100% of the county's residential thermal demand.

This report concludes by also acknowledging that there are many obstacles to the implementation of biomass energy. This includes economic feasibility, lack of an established supply chain, as well as concerns of emissions of particulate matter that can adversely impact human health. Recommendations going forward are to keep a close eye on the future development of biomass energy, as the technology to process and manage it is still in its infancy. The importance of analyzing locally sourced biomass of a county such as Tompkins is to see the potential that this type of energy can have in offsetting the use of fossil fuels and the potential for energy independence. Favorable future energy policies and development of future technologies to process bioenergy will be vital to the successful production and implementation of biomass energy.

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Introduction

As part of the Tompkins County's 2020 Energy Strategy, biomass was determined to be a viable alternative energy to mitigate the county's carbon footprint. Reduction in carbon emissions from rural residential heating would be an integral part of the county's goals of reducing 80% of its carbon footprint by 2050[1]. In order to reduce dependence on carbon-emitting fossil fuels, Tompkins County has taken the initiative to look into potential local biomass sources to meet heating needs. Biomass is considered an ideal alternative energy source for Tompkins County due to the abundant forest cover in the county. Additionally, brush land and inactive agriculture offers areas where biomass crops could be grown.

Existing forests will be considered as potential areas to harvest biomass, while inactive agriculture, and grassland will also be taken into account as possible locations for farming of switchgrass or willow for biomass production. This is a broad and preliminary study designed to complement a larger, longer, and more extensive study. Applied is a GIS analysis of the total forested, brush and grassland, and inactive agriculture area as potential sites for biomass production. The process progresses each step by subtracting areas with non-suitable attributes. The analysis concludes with a map illustrating the forests, brush and grasslands, and inactive agriculture suitable for biomass production. Additionally, inactive agriculture and marginal land provide the opportunity for growing bioenergy crops without competing with food production.

Forest wood, short rotation willow, and perennial switchgrass will be examined in terms of potential yield and economic value. Furthermore, this report will address the various challenges that the implementation of biomass energy production in the county face, as well as its place in the overall renewable energy market.

[1] Tompkins County Planning Department. "Tompkins County 2020 Energy Strategy." June 29, 2010. http://www.tompkins-co.org/planning/energyclimate/documents/DraftTompkinsCounty2020EnergyStrategy.pdf

Geospatial Analysis of Accessible Land

In order to determine the accessible acres of forest land, it is necessary to make several assumptions to remove areas from the analysis that may not be suitable for harvesting biomass. Although there are many considerations that may go into criteria of determining what is and what is not suitable, the following assumptions provide a starting point of assessing what the bioenergy extraction potential of Tompkins County could be.

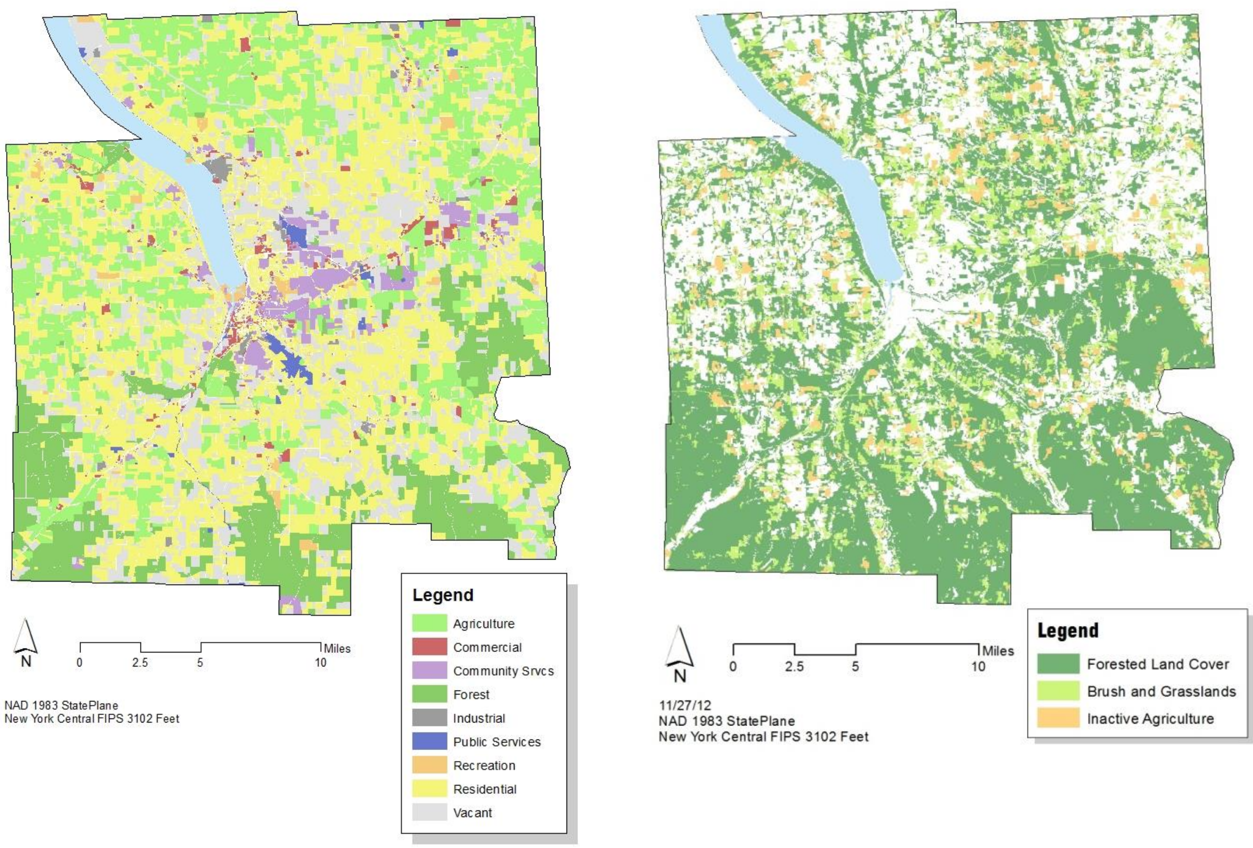

Figure 1: Parcel property class designation and existing Land Cover in Tompkins County (2007 CUGIR land use/land cover GIS data)

Assumptions

Unique Natural Areas (UNA)

UNAs were excluded from the analysis to determine accessible land for biomass production. This is because UNAs are given special consideration due to importance to the natural community, quality of ecosystem, rare or scarce plants or animals, geological importance, and aesthetic/cultural qualities. Many of these areas are heavily forested, which limits the regions that are available for biomass extraction.

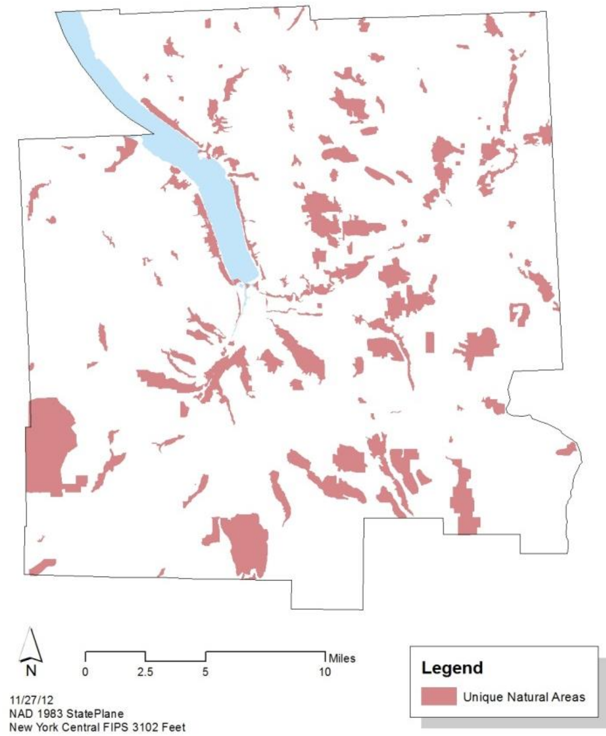

Figure 2: Unique Natural Areas in Tompkins County

Slope

Lands with slopes over 15% were excluded from the analysis to determine accessible land for biomass production. This is because steep areas are difficult for harvesting machinery, whether it is for a forest harvest or an agricultural harvest. There are environmental considerations as well, because sloped areas are subject to erosion if forest cover is removed. Farmers also consider land slopes greater than 15 degrees to be unmanageable for crops. Although many of the perennial biomass crops require little input and only one harvest per year, steep slopes complicate the germination period, as well as the harvesting period, due to machinery limitations.

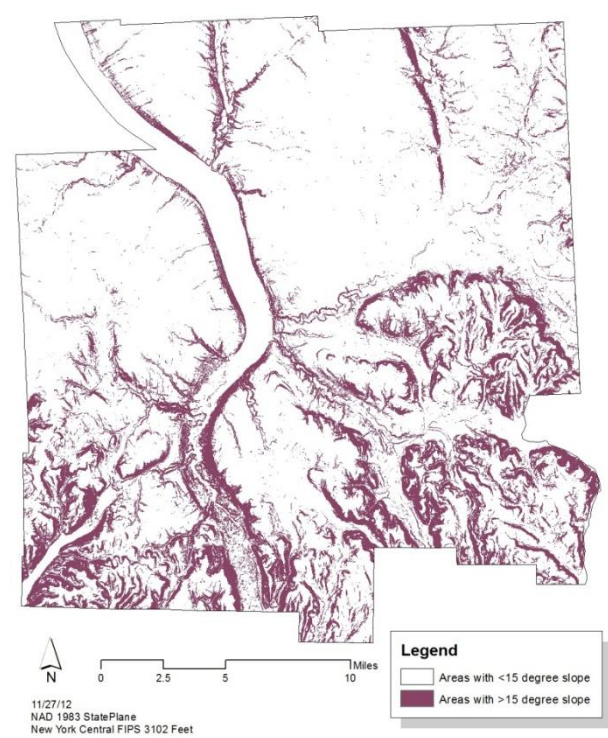

Figure 3: Areas with greater than 15 degree slope

Rivers

Buffers of 100 feet on either side of both intermittent and perennial stream centerlines were excluded from the analysis to determine accessible land for biomass production. This is because tree removals near streams, rivers, and waterways can have a negative environmental impact.This buffer is also placed on grasslands and inactive agriculture since converting these lands to agriculture production can affect stream health, though not as intensively as deforestation near streams.

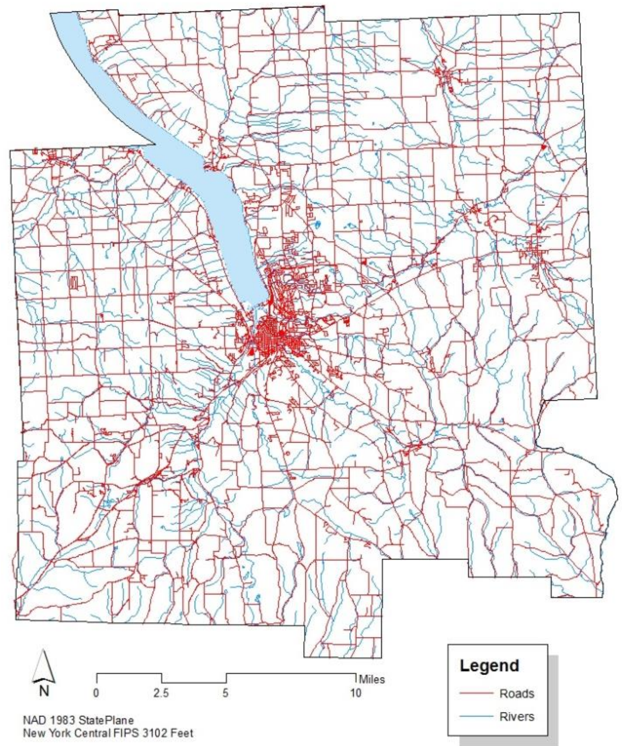

Figure 4: Roads and Rivers

Roads

Buffers of 100 feet on either side of road centerlines were excluded from the analysis to determine accessible land for biomass production. This is because of aesthetic purposes so roadsides once populated with trees will not be cleared for harvest. This buffer is also applied to inactive agricultural land and grasslands.

Ownership

Both public and private lands were included in the analysis to determine accessible land for biomass production. This is because forest cover is located on both privately owned parcels, as well as public land.

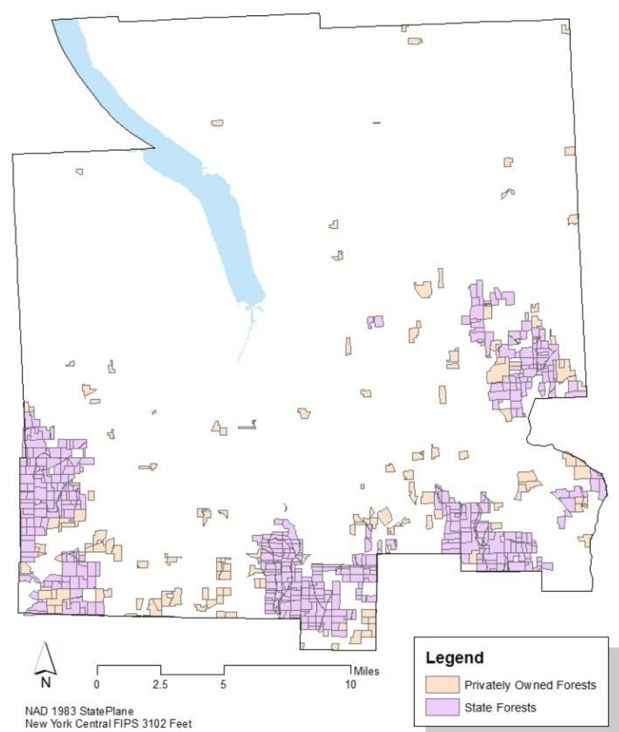

Figure 5: Parcels designated as forest

Parcel size

Parcels smaller than ten acres will be regarded as not available for biomass extraction. It should be noted that the Danby Land Bank Cooperative and similar projects in the county could make an exception to this assumption.

Non-GIS Based Assumptions

Transport costs

The viability of these sites will depend on their proximity to a facility where biomass can be transported and converted into energy. The longer the distance between the two sites, the less benefit accrued. For the purposes of this spatial analysis, the resource potential will be taken into consideration without these transport costs.

Technology adoption

This analysis assumes that homes in the county will be equipped or capable of being equipped with sufficient pellet or wood burning stoves for biomass thermal heating needs by the time biomass production is implemented.

Closed System

It is assumed that no import of export of biomass feedstock for the purposes of analysis, but in the real world situation, this would not be the case. Neighboring counties are realistically other potential producers or users, but this analysis only considers Tompkins County.

Data

File Name	Source	Definitions
Tompkins County land use/land cover (2007)	CUGIR	**Forest cover:** Fc: Coniferous Forest: Forested areas where needle trees, such as pine, spruce, fir and hemlock make up at least 80% of the tree cover. Fd: Deciduous: Forested areas where broadleaf trees make up at least 80% of the tree cover. Fm: Mixed forest: Forested areas with mixed coniferous and deciduous trees. The ratio of the predominant coniferous or deciduous tree stands must not exceed 80%. Fp: Forest Plantation: Rows of mature trees, primarily conifers, planted by man At: Tree farm: Areas used for cultivating trees, primarily Xmas trees. **Brush/Grassland:** Fb: Brush: Areas that have considerable growth of shrubs and small trees, but cannot be classified as forest. The brush land cover must occupy at least 80% of the delineated area. Forest and grassland may be incorporated into the remaining 20%. Fg: Grassland: Open grassy areas with no associated adjacent land uses. May include small amounts of shrubs, trees and brush. The grassland cover must occupy at least 80% of the delineated area. The remaining 20% may be trees, shrubs and brush. Grassland areas may be naturally occurring, or may be regularly mowed. **Inactive Agriculture:** Ai: Inactive Agriculture: Farmland and fields that appear to be no longer used for farming practices. Fields may appear to be growing over with tall grasses and small shrubs.
Tompkins County tax parcels (2011)	CUGIR	Residential Parcels less than 10 acres determined unsuitable as realistic extraction sites.
Unique Natural Areas	Tompkins County Planning Department	Unique Natural Areas (UNA) designated by Tompkins County restricted from deforestation
Tompkins County Elevation Map	Tompkins County Planning Department	Areas with higher than 15 degree slope assumed to be difficult for harvesting due to equipment limitations, potential for erosion, and manageability of agriculture.
Tompkins County Hyrdology Map	CUGIR	Areas near rivers not suitable for harvesting due to potential runoff and environmental impacts
Tompkins County Roads Map	CUGIR	Areas near roads not suitable for harvesting due to aesthetics purposes.

Methodology

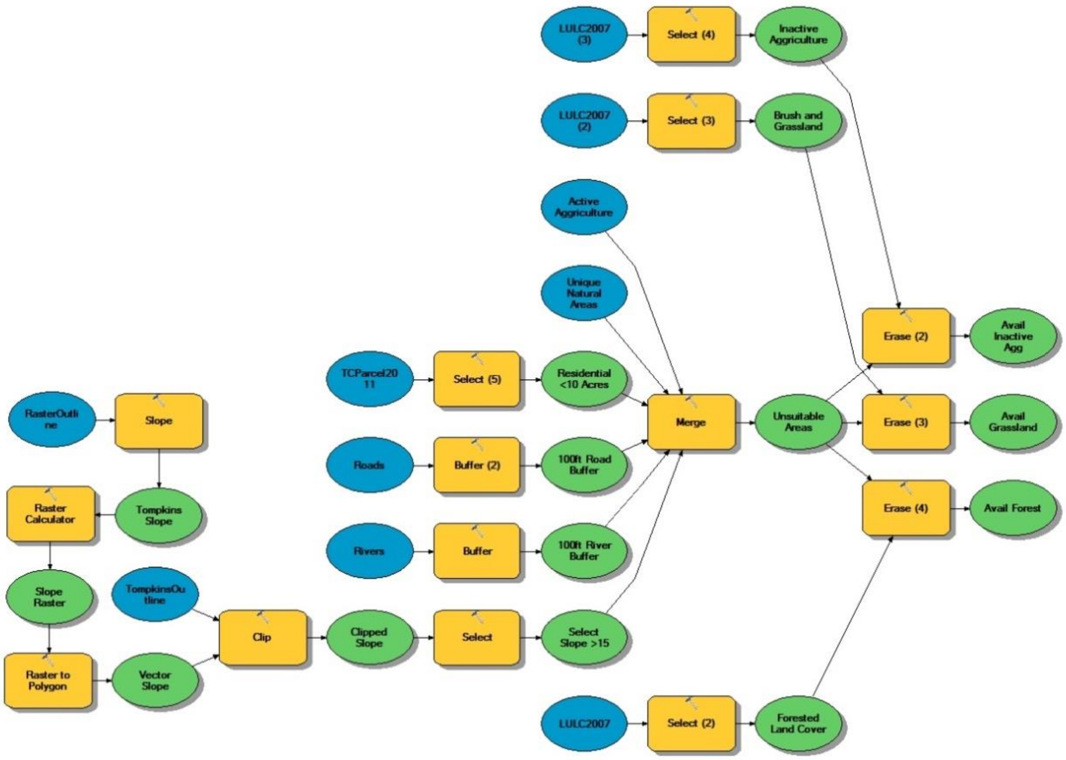

Figure 6: GIS model to remove areas unsuitable for biomass production or harvest

Results

Table 1: Accessible areas for biomass harvest and production in Tompkins County

Land cover	Existing Acres	Accessible Acres	%
Forests	140,262	57,170	41%
Inactive Agriculture	13,926	11,157	80%
Grasslands	39,217	23,269	59%

The GIS analysis of land cover shows that out of the 140,262 acres of forests, 57,170 acres are accessible for biomass harvest, which is 41% of the forestland in Tompkins County. Of the 13,926 acres of inactive agriculture, geospatial analysis showed that 11,157 acres meet the criteria. Out of the 39,217 acres of existing grassland, GIS analysis shows that 23,269 acres are available. These values can be considered conservative values because with the advent of better harvesting technology, 15% slope may not necessarily be such a limitation. Additionally, not all roads may necessitate a 100 ft. buffer in rural areas. With land banking collective practices, smaller residential plots could also be realistically considered. The resulting summary table and figure show that although most of the southern region of Tompkins County is abundant in forest, the rough terrain and the unique natural areas limit the availability and appropriateness of those areas for biomass harvesting.

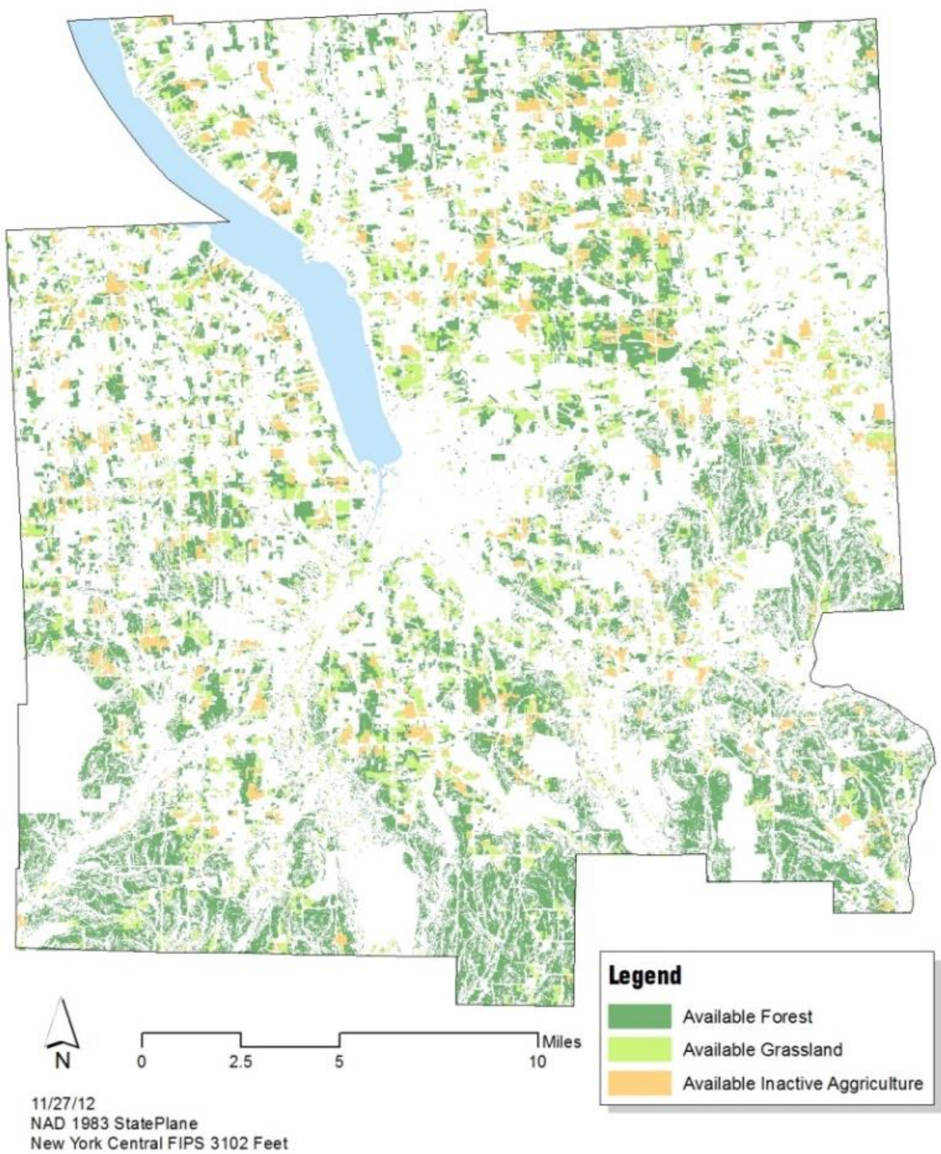

Figure 1: Results of GIS analysis: areas suitable for biomass extraction

Biomass from Forest Wood

Forest Resources

An important consideration for wood biomass purposed for energy is that it will primarily come from logging residues from conventional harvest operations and residues from forest management and land clearing operations. Secondary sources include wood processing mill residues and tertiary sources are urban wood residues such as construction and demolition debris, tree trimmings, packaging wastes, and other consumer durables. Additionally, some low-value soft wood trees could be harvested for energy production; some of which are currently harvested for firewood to heat woodstoves. Generally, woody biomass for energy production depends on other primary forest activity since higher grade timber can be purposed for other use. A summary of the forest resources under consideration is listed in the table below:

Table 2: Potential forest resources for biomass production[2]

Primary	
	• Logging residues from conventional harvest operations and forest management
	• Recovered residues generated from fuel treatment operations on forests
	• Direct use of fuel wood
Secondary	
	• Primary wood processing mill residues (i.e. saw mill)
	• Secondary wood processing mill residues (i.e. paper mill)
Tertiary	
	• Urban wood residues – construction and demolition debris, tree trimmings, packaging wastes and consumer durables

Carbon Mitigation

Forest biomass can mitigate carbon emissions in more ways than one. As a renewable resource, wood can be continually replenished, which leads to a more sustainable and dependable supply. Additionally, there are low net carbon dioxide emissions because the CO_2 generated during combustion of wood equals the CO_2 consumed during the lifecycle of the tree. Wood also contains minimal heavy metals and low levels of sulfur, and if standard emission control devices are used, there are minimal particulate emissions as well.[3] Besides being a potential resource for bioenergy, forest sequestration captures the carbon emissions as a natural process in the carbon cycle. Tompkins County has current biomass sequestration rates of 121 Gg C/yr[4] from all

[2] (Perlack and et. al. 2005) p.4
[3] (Bergman 2004)
[4] Gigagrams of carbon per year; 1 gigagram is equivalent to 1,102 short tons.

biomass sources, including forest, cropland, inactive cropland, and soil. Forests account for 75 Gg C/yr of the overall biomass sequestration in the county.[5] The existing stock of carbon stored in the forests of Tompkins County is summarized in the table below:

Table 3: Total Carbon in Tompkins County Forests[6]

Item	Carbon (short tons)
Above ground carbon in live trees	4,633,635
Below ground carbon in live trees	921,132
Total carbon in Tompkins' forests	**5,554,767**

In other words, at a sequestration rate of 75 Gg C/yr, forests in Tompkins County can sequester over 82,650 short tons of carbon per year[7]. Therefore, a passive approach to sustainable forest management by just letting the trees grow can already offer an effective method for carbon emission mitigation. Conversely, forest biomass extraction does not necessarily counteract sequestration rates because growing forests can sequester more carbon than older trees in fully matured forests. If sustainable harvesting practices are implemented, Tompkins County can further mitigate carbon emissions through biomass energy production from local forests and utilizing that energy in place of combustion of fossil fuels. It is necessary to analyze not only how much forest is in the county, but also forest growth rate, so biomass extraction does not exceed the forest biomass that will regrow in any given year.

Existing Resource in the County

According to the 2011 U.S. Forest Inventory and Analysis database, there are a total of 141,225 acres of forested land in the county. This equates to approximately 46% of the county's 304,640 acres. Of the forested lands, 25,900 acres are owned by state or local government, and 115,325 acres (82% of forested land) are privately owned as shown in the following tables:

[5] (Vadas, Fahey and Sherman 2007)
[6] USDA Forest Service. "55.1 – Above and belowground carbon in live trees (at least 1 inch d.b.h./d.r.c.), in short tons, by species group and diameter class" http://www.fia.fs.fed.us
[7] (75 Gg C/yr) * (1,102 tons/Gg) = 82,650

Table 4: Area estimate of Tompkins County forest land by forest type group and stand size (in acres), in 2011[8]

Forest-type group	Stand-size class				Total
	Large Diameter	Medium Diameter	Small Diameter	Nonstocked	
White / red / jack pine group	9,514	--	--	--	9,514
Exotic softwoods group	--	5,566	1,855	--	7,421
Oak / pine group	10,903	--	--	--	10,903
Oak / hickory group	29,685	13,403	3,286	--	46,374
Elm / ash / cottonwood group	1,643	--	--	--	1,643
Maple / beech / birch group	40,859	15,622	--	--	56,481
Aspen / birch group	--	3,999	--	--	3,999
Other hardwoods group	3,557	--	--	--	3,557
Nonstocked	--	--	--	1,333	1,333
Totals:	96,161	38,590	5,141	1,333	141,225

Table 5: Area estimate of Tompkins County forest land by forest type group and ownership group (in acres) in 2011[9]

Forest-type group	Ownership group		Total
	State and Local Gov't	Private	
White / red / jack pine group	3,864	5,650	9,514
Exotic softwoods group	--	7,421	7,421
Oak / pine group	5,338	5,566	10,903
Oak / hickory group	16,698	29,676	46,374
Elm / ash / cottonwood group	--	1,643	1,643
Maple / beech / birch group	--	56,481	56,481
Aspen / birch group	--	3,999	3,999
Other hardwoods group	--	3,557	3,557
Nonstocked	--	1,333	1,333
Totals:	25,900	115,325	141,225

The USDA Forest Service Forest Inventory Analysis (FIA) data shows that Tompkins County has a tree inventory of 64 million trees in the county if counting all trees over 1 inch dbh (diameter at breast height). However, harvestable timber generally applies to trees over 5 inch

[8] USDA Forest Service. " 2.4 - Area, in acres, by forest-type group and stand-size class" *Forest Inventory and Analysis.* n.d. http://www.fia.fs.fed.us.
[9]USDA Forest Service. " 2.3 - Area, in acres, by forest-type group and ownership group " *Forest Inventory and Analysis.* n.d. http://www.fia.fs.fed.us.

dbh. This number equates to 21 million trees, which is equivalent to 9.2 million green tons of biomass.[10]

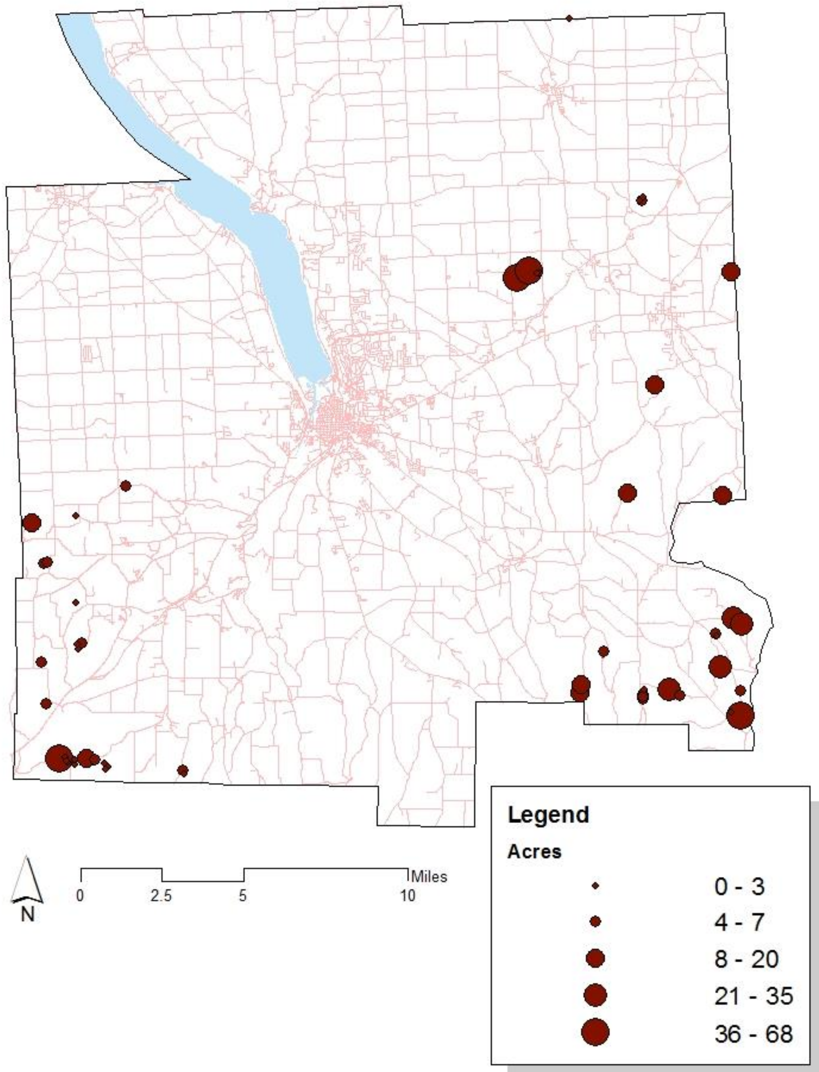

Figure 8: Sites of current logging activity in Tompkins County (Data from 2007 CUGIR land use/land cover)

Forest Growth Rate

Another consideration is that unlike bioenergy crops, forests take longer to regrow, so the harvest site will have to rotate with each harvest over a period of years to allow for regrowth. The extraction rate of forest wood should not exceed the growth rate in the region, as it becomes

[10] USDA Forest Service. “10.2 - Aboveground dry weight of standing-dead trees (at least 5 inches d.b.h./d.r.c.), in short tons, by species group and diameter class.” http://www.fia.fs.fed.us

counterproductive to natural forest sequestration activity and would raise conservation concerns. The gross annual growth of forest biomass in Tompkins County is 281,094 green tons annually according to FIA data. Existing removals of forest biomass in Tompkins County are 40,945 green tons annually, which includes all forest extraction activity such as logging, forest management, and firewood extraction.[11] Annual tree mortality of 139,785 green tons accounts for natural causes not directly associated with human activity. By deducting the annual biomass removals and biomass morality rate from the gross annual growth, the net annual growth of forest biomass comes out to 100,346 green tons, which is 1.1% of the forested biomass in the county. Therefore, this would be the maximum allowable annual biomass extraction from forests assuming the county does not want to decrease the net annual growth of forest.

Table 6: Annual green tons of forest biomass sustainably harvestable in Tompkins County

Item	Annual value, green tons
Gross Annual Growth	281,094
-Removal	40,945
-Mortality	139,785
Net Annual Growth	**100,364**
÷ Total Forest Biomass	9,267,269
Sustainable Annual Forest Harvest	**1.1%**

Forest Residues

Since the supply of the wood chips depends heavily on low-value wood residue availability through harvesting operations or secondary wood processing, it is difficult to determine the actual yield that each acre of forest can provide for biomass energy production. The average biomass density of forests in Tompkins County is 65 green tons per acre[12], but removals usually involve primary forest harvest operations such as logging or fuel treatments, so the potential yield of the remaining wood residue is considerably less than 65 tons/acre. Residue removals on average can range from 1 dry ton per acre up to 10 dry tons per acre depending on the tree species[13], logging efficiency, and ultimately on the amount that is removed since leaving some

[11] Firewood extraction can be an informal process and there is no accurate data currently available.
[12] 9.1 million green tons ÷ 141,225 forested acres
[13] Assuming 45% percent moisture content of wood, 1 dry ton = 2.2 green tons

wood residue is ecologically beneficial for forest regrowth. Dead trees left on site are an important part in maintaining ecological health, as dead trees serve an important role for wildlife habitat[14]. According to the National Renewable Energy Laboratory (NREL) it is estimated that from regular forest operations, Tompkins County has an estimated 10,000-25,000 annual dry tons of forest residues left at sites[15]. This only includes wood residues left at site and does not include residues already used and accounted for, as it is estimated that half of the residues are already being used for other purposes such as mulch or removed from forests as firewood.

Potential Yield of Forest Wood

The numbers in the following table are practical values used to calculate the potential energy yield of forest wood residues. By factoring in the actual available biomass production area deduced from the previous GIS analysis, it is possible to quantify the amount of biomass that could be produced on the available land:

Table 7: Potential yields from forest wood (dry tons)[16]

Fuel	Forest wood chips[17]
Tons/acre	1.1
Moisture	50%
Btu/lb (0% MC)[18]	8600
Gross Heating Value [19] (MMBtu/ton, 0% MC)	17.2
MMBtu/acre	18.9

Since it was determined that 57,170 acres of forest land will be accessible for forest harvest, the annual potential biomass that can be extracted from forests would be approximately 63,000 dry tons since 1.1 dry tons/acre is the yield. This method uses the land area constraint to determine the estimated woody biomass. Another method that could be used is using the constraint of forest growth. Assuming a sustainable forest management practice is to not reduce net growth of forest, the annual limit of biomass removals would be equal to the net growth rate of 1.1% of the total

[14] (Hassinger 2008)
[15] http://www.nrel.gov/gis/biomass.html
[16] (Timmons, Allen and Damery 2008),
[17] (Innovative Natural Resource Solutions 2007)
[18] http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf
[19] Gross heating value = BTU/lb * 2,000lb/ton ÷ 1,000,000BTU/MMBTU

forest, or 100,364 green tons. If it is assumed that the ratio of removals to forest residue stays consistent with future harvest operations, the following relationship could be made based off of FIA data for removals and net growth, as well as NREL data for estimated forest removals[20]:

$$\frac{Current\ Removals}{Current\ Residues} = \frac{Future\ Removals}{Future\ Residues}$$

$$\frac{40{,}000\ green\ tons}{25{,}000\ dry\ tons} = \frac{100{,}000\ green\ tons}{Future\ Residues}$$

$$Future\ Residues = 63{,}000\ dry\ tons$$

This assumes that on top of the 15,000 tons of estimated forest residue, there are also around 10,000 tons of uncounted residue used for fire logs, mulch, or other end uses of scrap wood that is related to forest operations. The amount of harvestable biomass from forests came out to be 63,000 dry tons/acre using both area constraints and forest growth constraints. Note that it is assumed that extracting forest biomass for energy must be a secondary process to logging and other standard forest operations. However, even if the economics could work to clear cut a forest for the sole purpose of using wood for energy, the annual forest growth constraint of 100,000 green tons still apply.

The gross heating value of wood chips is 8,600 Btu/lb at 100% efficiency, which means 0% moisture content.[21] The actual energy that is provided to the end user is less due to losses. Even wood that is classified as dry weight has some percentage of moisture. Therefore, in order to determine the amount of heating energy that each biomass source has, it is necessary to account for the losses due to steam produced by burning hydrogen, loses due to additional moisture content, as well as excess air. The potential energy yield per ton of forest residue would be 17.2 MMBtu/ton.

For residential uses of wood for fuel, most common types of furnaces use split lengths of firewood or pelletized wood. The Tompkins County Planning Department estimates that the

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[20] Assuming 10,000 tons of uncounted residue is currently used on top of the 15,000 tons left at site for total current residuals from operation at 25,000 tons. Also it is assumed all future residue will be used for energy.

[21] (Jenkins 1993)

average home in the county requires 61.2 MMBtu to heat annually.[22] According to the U.S. Environmental Protection Agency (EPA), the net efficiency of catalytic wood stoves and pellet stoves can have, on average, efficiency values of 68%, so there are losses when calculating the thermal energy that actually gets converted to heat.[23] The average home in the county would therefore require 5 acres of forest land to heat it for a year.[24] If all available forest land is utilized for biomass extraction, approximately 12,000 homes could be heated annually. This is calculated by multiplying the potential energy yield per ton of 17.2 MMBtu/ton by 63,000 tons of annual harvested forest biomass to get 1,083,600 MMBtu of thermal heat that can be theoretically provided. Multiplying by 68% efficiency, the actual amount of energy that is realized as thermal heat is 736,848 MMBtu. Then, divide this value by 61.2 MMBtu, since that is the annual demand of thermal heat for the average home in Tompkins County to arrive at 12,040. The U.S Census 2007-2011 American Community Survey estimates that Tompkins County has a total of 41,528 housing units.[25] Therefore, utilizing all the available forest land could meet the thermal demand of 29% of the housing units in the county.

[22] (Tompkins County Planning Department 2008)
[23] (U.S. Environmental Protection Agency 1996)
[24] (61.2 MMBtu ÷ 18.9 MMBtu/acre)*68% efficiency
[25] (U.S. Census 2011)

Biomass from Bioenergy Crops

Another viable source of biomass energy could be from short rotation woody crops and perennial warm season grasses. Specifically, shrub willow and switchgrass have been determined to be well suited for cultivation in the Northeast and preliminary trials have shown a potential for these crops for bioenergy production. Marginal and underutilized land in Tompkins County, as well as neighboring counties in New York State, are possible sites to grow bioenergy crops without interfering with primary agricultural land reserved for food production. There are approximately 22,000 acres of marginal brushland and 14,000 acres of inactive agriculture in the county according to the Energy and Greenhouse Gas Emissions Element 2008 Amendment to the Tompkins county Comprehensive Plan. Since agricultural food crop production is not suitable on marginal lands, growing bioenergy crops will not conflict with food production. From some studies, it also appears that prices for both willow and switchgrass would be higher than current prices of forest woodchips.[26]

Wood crops for bioenergy

Shrub willow, and other short rotation woody crops are unique in that they can produce environmental and rural developmental benefits in addition to bioenergy or other bioproducts. On certain marginal lands that have hydrological issues, willow can act as riparian buffer strips. Contaminated or agriculturally unproductive fields can benefit from bioenergy crops as a means of phytoremediation and brownfield restoration as an integral part of balancing a nutrient and waste management system.[27] Willow also produces uniform feedstock and is easily established with unrooted cuttings, with the ability to re-sprout vigorously after each harvest. Additionally, having few pest problems and having a wide range of genetic variability means that the high biomass production potential of willow can only increase in the future. Larry Smart, associate professor in the department of horticulture at Cornell University, believes that the production cycle of willow and other perennial crops can come close to 100% carbon closure[28]. He mentions that willow deposits more net carbon in the soil than agricultural crops. Additionally, waste

[26] (Timmons, Allen and Damery 2008)
[27] (Abrahamson 2006)
[28] 2013 Spring presentation by Larry Smart in BEE 6940; reference: http://www.upbiofuel.com/wp-content/uploads/2012/06/2004-Willow-biomass-crops-study.pdf

water from waste water treatment plants can work as fertilizer with the willow, as willow is capable of absorbing toxic metals such as cadmium through a phytoremediation process.

The production cycle of willow biomass involves minimal maintenance, after the first year planting period when it is the most sensitive. It is coppiced every year and can be harvested every three years for over two decades. Each acre of willow biomass crop can optimally produce 5 dry tons per acre annually.

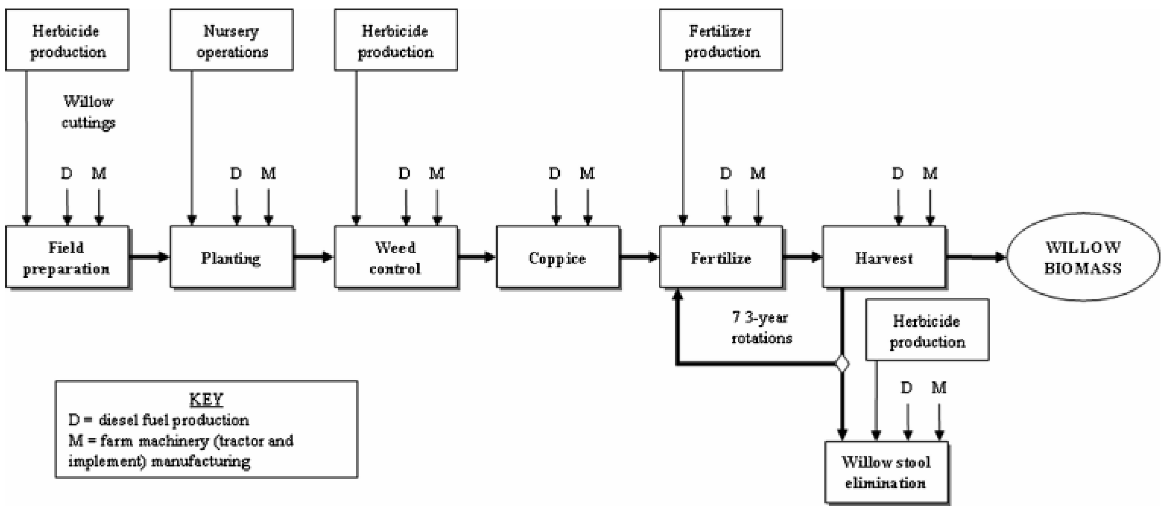

Figure 9: Schematic of willow biomass production processes and inputs. (Keoleian and Volk 2005)

Year	Season	Activity
0	Fall	Mow, contact herbicide, plow, disk, seed covercrop, cultipack
1	Spring	Disk, cultipack, plant, pre-emergent herbicide, mechanical and/or herbicide weed control
1	Winter	1st year coppice
2	Spring	Fertilize
3		
4	Winter	1st harvest
5	Spring	Fertilize
6		
7	Winter	2nd harvest
(8–22)		(Repeat 3 year cycle for 3rd–7th harvest)
23	Spring/Summer	Elimination of willow stools

Figure 10: Willow biomass crop field operation timeline

Grass Crops for bioenergy

As with willow, switchgrass is a native species to the Northeast that requires minimal input as a managed crop for bioenergy production. Switchgrass and other warm season perennial grasses can be grown on marginal lands that are poorly drained, sloping, shallow, or pH imbalanced to put underutilized land back into production. Grasses can be pelletized for use in pellet boilers or used for other end uses such as animal bedding and hay. Unlike woody biomass, grasses can be baled and left on site to dry so moisture content is considerably lower than wood biomass. Conservative yield estimates for grasses are 3 dry tons per acre annually[29], but Hillary Mayton, Cornell professor in the department of plant breeding and genetics believes 5 dry tons per acre per year is possible. Grass pellets may be more easily produced as dry fuel than willow due to the lower inputs needed. With lower moisture content, less input is needed for drying and pelletizing as well, so switchgrass pellets are better adapted to meet small commercial and residential heating needs. According to Mayton, another argument for switchgrass is that it can be a versatile crop that could be used for other purposes such as forage hay and for use in growing mushrooms. Therefore, even if the demand for biomass energy feedstock is unstable, the other potential uses for switchgrass make this an attractive crop, especially on marginal inactive agricultural land.

Table 8: Bulk density of switchgrass[30]

Form of biomass	Shape and size characteristics	Density (kg m-3)
Chopped biomass	20-40 mm long	60-80
Ground particles	1.5 loose fill	120
Baled biomass	Round or large squares	140-180
Ground particles	1.5mm pack fill	200
Briquettes	32 mm diameter x 25 mm thick	350
Cubes	33 mm x 33 mm cross section	400
Pellets	6.24 mm diameter	500-700

[29] (Jyväskylä Innovation Oy & MTT Agrifood Research Finland 2009)
[30] (Sokhansanj 2009)

Potential Yield of Bioenergy Crops:

Table 9: Potential energy yield of bioenergy crop resources

Fuel	Coppiced willow chips	Switchgrass
Tons/acre	4.7	4.0
Moisture	50%	12%
Btu/lb (0% MC)[31]	8200	7900
Gross Heating Value [32] (MMBtu/ton, 0% MC)	16.4	15.8
MMBtu/acre	77.1	63.2

For a willow crop that is harvested every three years, the actual harvest in year three is approximately 30 green tons/acre, but when averaged out on an annual basis, the yield would be 10 green tons/acre/year, which is equal to 5 dry tons assuming 50% moisture content. Note that the yield of willow and switchgrass per acre in the table above are both lower than the previously mentioned optimistic values of 5 dry tons per acre. Timothy Volk from the Department of Forest and Natural Resources Management in SUNY College of Environmental Science and Forestry suggests that willow crop has yield of 4.1 dry tons per acre in the Northwest region[33]. Likewise for switchgrass, 5 tons/acre is optimistic and a value of 4 tons/acre would be a closer estimate considering places in Europe with developed bioenergy programs such as Finland estimate true grass yields of 3 tons/acre by taking into account harvest losses.[34]

As a fast growing woody crop, willow is a good alternative for forest biomass, with a theoretical energy yield of 8,200 Btu/lb. Switchgrass and other grass biomass have a lower heat content of 7,900 Btu/lb. The gross heating value of willow chips and switchgrass is 16.4 MMBtu/ton and 15.8 MMBtu/ton respectively.

For residential uses, willow could be used in the form of woodchips or pellets, and switchgrass could be used in pellet form. As with the calculations for the forest biomass, the following calculations will assume Tompkins County Planning Department estimates that the average home in the county requires 61.2 MMBtu to heat annually. Additionally, the EPA's estimate on

[31] http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf
[32] Gross heating value = BTU/lb * 2,000lb/ton ÷ 1,000,000BTU/MMBTU
[33] (Volk, et al. 2004)
[34] (Jyväskylä Innovation Oy & MTT Agrifood Research Finland 2009)

the average net efficiency values of 68% will be applied to all stoves utilizing either willow chips, pellets, or grass pellets – even though the actual equipment required to combust the different forms actually varies. Since biomass crops give higher energy yield per acre, with willow at 77.1 MMBtu/acre and switchgrass at 63.2 MMBtu/acre, it takes less land to heat a standard home. If biomass crops are used for residential heating, it would take 1-2 acres to meet the thermal demand of each home annually.[35] If all the 35,000 acres of available inactive agricultural land and grassland is converted to willow production, since it is the higher energy yielding crop, the expected annual production of willow biomass would 165,000 dry tons if using and expected yield of 4.7 tons/acre. This means that this source could meet the thermal demands of over 30,000 homes in the county. This is calculated by multiplying the potential energy yield per ton of 16.4 MMBtu/ton by 165,000 annual tons to get 2,706,000 MMBtu of thermal heat that can be theoretically provided. Multiplying by 68% efficiency, the actual amount of energy that is realized as thermal heat is 1,840,080 MMBtu. Dividing this value by 61.2 MMBtu gives a value of 30,066. Since the U.S Census 2007-2011 American Community Survey estimates that Tompkins County has a total of 41,528 housing units, bioenergy crops could meet the thermal demand of 72% of the homes in the county.[36]

[35] 61.2 MMBtu ÷ (77.1MMBtu/acre * 68% stove efficiency)
[36] (U.S. Census 2011)

Conclusions

Table 10: Land Constraints

Land cover	Existing Acres	Accessible Acres	%
Forests	140,262	57,170	41%
Inactive Agriculture	13,926	11,157	80%
Grasslands	39,217	23,269	59%

Table 11: Yield Constraints

	Forest wood chips	Coppiced willow chips	Switchgrass
Tons/acre	1.1	4.7	4.0
Moisture	50%	50%	12%
Btu/lb (0% MC)[37]	8600	8200	7900
Gross Heating Value [38] (MMBtu/ton, 0% MC)	17.2	16.4	15.8
MMBtu/acre	18.9	77.1	63.2

Table 12: Biomass energy potential in Tompkins County (annually)

	Forests	Biomass crops
Production (tons)	63,000	165,000
Energy potential (MMBtu) @ 100% eff.	1,083,600	2,706,000
Homes heated	12,040	30,066
% of homes in county	29%	72%

By using the approach of discerning available land for biomass production for both forests and bioenergy crops, analysis concludes that 100% of the county's residential thermal demand could be met by implementation of both biomass production strategies. However, this would require converting almost a quarter of Tompkins County's land area into biomass production in order to achieve this goal. Additionally, there are several unaddressed issues of why biomass energy is not currently implemented at a large scale. The current economic climate does not favor bioenergy crop production, and considering that a standard willow crop has a lifespan of over two decades, the uncertainty of a practically non-existent biomass energy market makes this an

[37] http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf
[38] Gross heating value = BTU/lb * 2,000lb/ton ÷ 1,000,000BTU/MMBTU

unattractive venture for land owners. Some lower grade stoves and other combustion equipment offer low efficiency and create additional challenges of dealing with emissions of particulate matter.

Recommendations

There are several key points that will lead to future utilization of locally source of biomass for Tompkins County. The first is that although it is possible to assess and estimate the potential of resources within the county boundaries, it is important to consider that Tompkins County is not an island. Further analysis should be done in the Northeast region to determine what role the county plays in the bigger picture to get a better understanding of the available biomass resources. Economic feasibility of biomass energy utilization is vital in the future use of these resources. Considerations should include reducing harvesting and transportation costs, increasing yields, and improving processing efficiency. If better economic incentives can be put in place for both producers and end users, those that value the environmental and rural developmental benefits associated with biomass can compete in the energy market. Some non-technical barriers can be overcome by getting greater support for biomass among the public, policy makers, NGOs, and industries.[39]

Policy Support

European countries such as Austria and Finland have robust biomass energy production systems that power a majority of their residential heating needs. This is made possible because of heavy subsidies and governmental policies that support the renewable industry. In order for Tompkins County to move forward, effective policies at the local, state and federal level need to offer support for new biomass energy initiatives. The U.S. has developed some programs that may be beneficial for future development of biomass energy[40]:

- *Renewable Energy Production Tax Credit (REPC)*: Federal program offering a tax credit for electricity generated by qualified renewable energy sources.
- *Conservation Reserve Program (CRP):* A program that offers 50% reimbursement for eligible establishment costs and helps agricultural producers safeguard environmentally

[39] (Abrahamson 2006)
[40] (Hornesky 2013)

sensitive land. Participants in CRP plant long term resource-conserving covers to improve water quality, control erosion of soils and enhance wildlife. Tree and shrub plantings, as well as cool and warm season grasses are eligible.

- *Environmental Quality Incentives Program (EQIP):* Voluntary program providing financial and technical assistance to eligible agricultural producers willing to address priority environmental issues. This offers financial incentives to manage forest according to a NYS DEC stewardship plan. Benefits of this program are that it helps promote sustainable forest management.
- *Biomass Crop Assistance Program (BCAP):* This program provides financial incentives to private landowners to produce biomass crops for energy. The main target is shrub willow that can produce large numbers of woody biomass. Producers are required to have an agreement setup with a qualified biomass conversion facility. If landowners in Tompkins County want to utilize this program, they can work with ReEnergy Holdings LLC, a local processing plant with facilities in Lyonsdale, Chateaugay, and Black River.

Sustainable Forest and Agriculture Management

Growing forests offer more benefits to carbon sequestration, so regular forest thinning is beneficial to the health of the forest and enhances wildlife habitat diversity. There are a couple opportunities for Tompkins County to take low cost approaches to forest management using some agroforestry techniques.

- *Silvopasturing:* By combining livestock grazing on forested land, silvopasturing is an innovative agricultural practice done in many parts of the world. It involves the deliberate the deliberate and managed production of livestock and timber on the same land cover over an extended period of time. Livestock fertilize the land and trees can be thinned and harvested.
- *Afforestation Practices:* Forest activities in Tompkins County should not exceed the annual growth of 100,000 green tons of forest biomass. Additionally, maintenance of regeneration and harvesting activities should be observed closely. Fallow or deforested lands should be considered a priority for regeneration.

County Initiatives

The Danby Land Bank Cooperative is an organization that solves the problem of small acre parcels of land and helps work with land owners to put underutilized land into grass and wood pellet production by forming a large enough agricultural base to provide economies of scale. Since social norms and customs are a roadblock to biomass energy acceptance, cooperatives such as the Danby Land Bank offer an opportunity of scale and collaboration among people interested in having locally sourced biomass energy in Tompkins County.

Technology

New advances in plant genetics can improve the yield and growth rates of willow, switchgrass, and other biomass crops. Improvements in harvesting machinery and methods will also contribute to greater yields in the future. Technology is also improving the efficiency of wood stoves and burners in producing energy, as well decreasing particular matter emissions during combustion.

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